Design Course

Ceramics

An Exploration of Form through Ceramics

by
Mohsen Jafaarnia and Prof. Ravi Mokashi Punekar
DoD, IIT Guwahati

Source:
https://www.dsource.in/course/ceramics

1. Introduction
2. Ceramics
3. Material of Ceramic
4. Preparation of Materials
5. Types of Manufacturing
6. Liquid State Forming
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https://www.dsource.in/course/ceramics/introduction

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Introduction

Designing a product involves an understanding of the processes involved that are most appropriate in the final creation of the product form. It is more than an exercise in concept generation or form generation. The development of the final product involves thorough understanding of the availability of suitable materials, selecting a feasible manufacturing process amongst the vast range of alternatives.

To select an appropriate process for an effective and efficient design, the designer should be able to critically understand the possibilities as well as the limitations of each process.

Processing ceramic material, although one of the oldest manufacturing processes, continues to be preferred technique for form exploration in the preliminary stages of product simulation. The low cost of the raw materials and the process seems to be the primary reason for this.

This course '**Introduction to Ceramic Processes**' is an introductory course to the basic processes that a designer can use for simulating design concepts around product form, that are either symmetric about an axis or that can be extruded.

The course introduces simple 'Do it yourself' techniques in generating different shapes and forms. The course is comprehensive with the basic ceramic processing techniques like roto-forming and extrusion with the use of simple templates, fixtures made from available materials.

The course ensures fascinating exploration of form through ceramics.

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Ceramics

The word "ceramic" comes from the Greek word κεραμικός(keramikos), "of pottery" or "for pottery", from κεραμικός (keramos), "potter's clay, tile, pottery"
[source : http://en.wikipedia.org/wiki/Ceramic].

It is an inorganic, nonmetallic solid prepared by the action of heat and subsequent cooling. Ceramic materials can be crystalline or can be amorphous like glass.

The earliest known use of ceramics was for making pottery with clay alone or mixing with other materials. The objects were then hardened in fire and glazed to create a colored, smooth surface.

Engineering ceramic structural parts provide greater strength, are light in weight and corrosion resistant and hence, best suited for applications at extremely high temperatures and in highly corrosive environments. Ceramic engine components permit efficient burning of fuel at higher temperatures and eliminate the need of a cooling system. Other uses include making of cutting tools, valves, bearings and chemical- processing equipment. In the electronic industry, ceramic materials are used for making chips, superconductors, magnets, capacitors and transducers.

Ceramic is cheap due to the abundance of its raw materials. Being brittle, ceramic is reinforced with fibers or whiskers to increase ductility and toughness.

Today, by the development of advanced engineering, ceramics is used not only in making traditional art objects but also in industries like aerospace, mining, medicine, etc.

e.g. The properties of ceramics make it most suitable for applications in aerospace industry. The figure shows the Simulation of the outside of the Space Shuttle as it heats up to over 1,500 °C (2,730 °F) during re-entry into the Earth's atmosphere.

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Animation:

- http://kulraj-the-numismatist.blogspot.com/2011/01/one-rupee-coins-xi.html
- http://www.rubberducks.org.uk/about.php
- http://bikereviews.com/2009/11/bern-watts-carbon-fiber-helmet/
- http://global.rakuten.com/en/store/tennis-c/item/c11060070c/
- http://www.indiamart.com/bianca-impex/other-products.html
- http://glass-table.blogspot.com/2011/05/modern-glass-coffee-table.html

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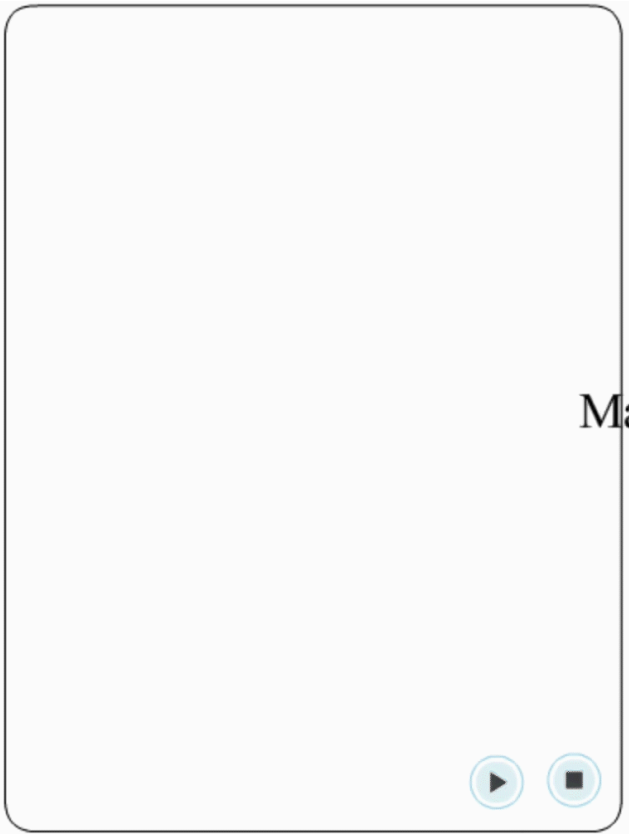
Material of Ceramic

Different types of Materials used for Ceramics:

Types of Materials:
A product is made up of one or more materials depending upon the ease of manufacturing, availability of materials, desired properties of the final product, etc. Materials around us can be classified as follows :

- Metals
- Plastics
- Rubbers and Elastomers
- Natural engineering materials
- Natural materials



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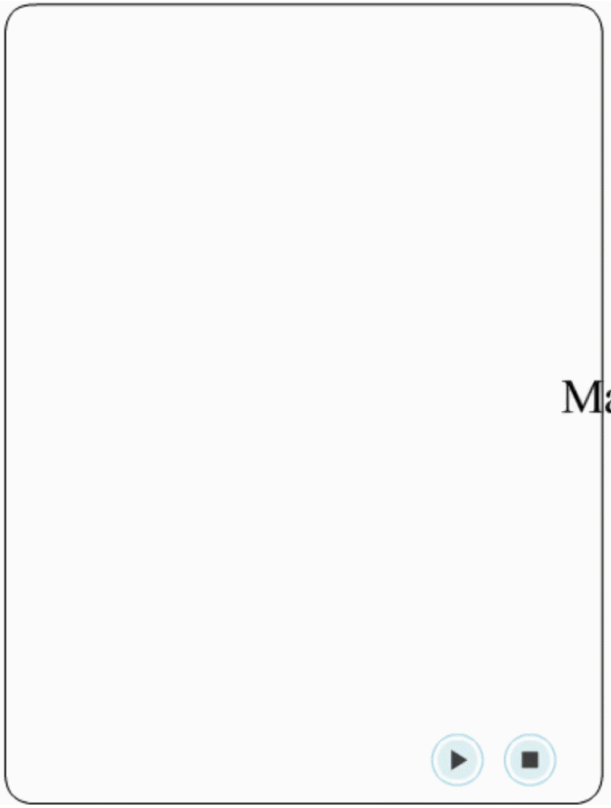
The difference between natural materials and engineering materials is that most of the sources for natural materials are from nature itself.

Due to the ever-increasing demands of high performance materials, there is substantial development in the invention of new materials. Materials acquire distinct properties according to the percentage of the ingredients present in it. These newly developed combinations have better properties like improved strength, corrosion resistance, dimensional stability, heat resistance, etc. unavailable in a single material.

These new combinations of materials can be segmented as follows:

- Carbon
- Glass
- Ceramics
- Refractory hard metals



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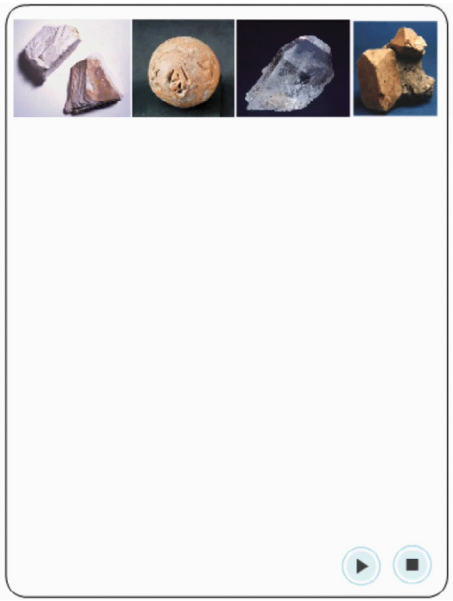
Materials used for Ceramics:
The earliest known material used in ceramics was clay alone or clay mixed with some other additive material. With the flow of time, engineering ceramics have undergone innumerable changes in their constituents and their proportions added to make better ceramics. Depending upon the combination of the constituents and their proportions, ceramics are used for making products that are either traditional, industrial, building products or art objects. New ceramic materials are developed to be used in advanced ceramic engineering.

For Art and traditional ceramics, designers can use the ingredients in the following proportion to prepare different materials of ceramics:

- Ball clay 25%
- Kaolin 28%
- Quartz 32%
- Feldspar 15%

Further, in this combination Ball clay has different proportions of individual constituents as follows:

- Kaolin 20 – 80%
- Mica 10 – 25% (picture given below)
- Quartz 6 – 65%



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http://mineral-metals.exportersindia.com/products/mica-mica-products/mica-mineral.htm

Animation:

- http://biz-chemical.com/Kaolin.htm
- http://en.wikipedia.org/wiki/File:Clay_ball_cypro-minoan_Louvre_AM2335.jpg
- http://www.amgueddfacymru.ac.uk/cy/800/?mineral=253
- http://www.chemicalsandminerals.net/feldspar-powder.htm

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Source:
https://www.dsource.in/course/ceramics/preparation-materials

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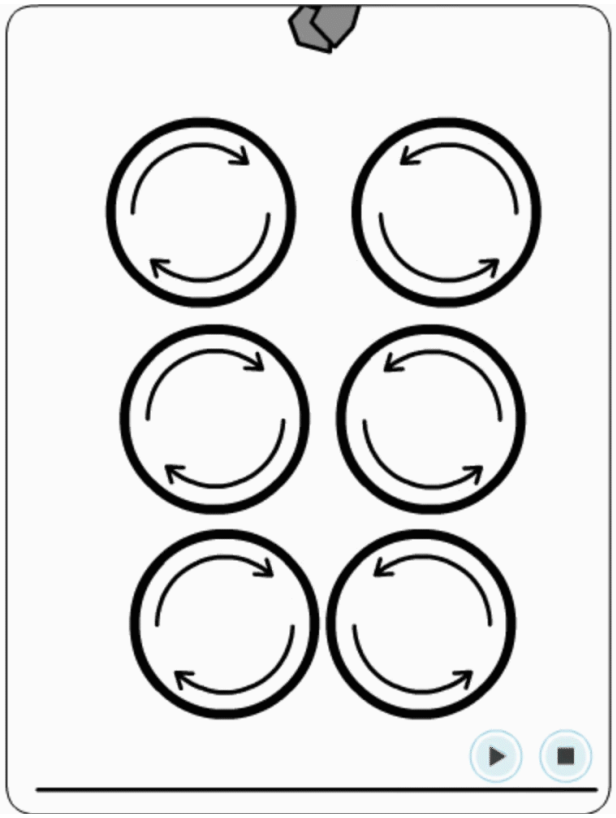
Preparation of Materials

The primary step in the preparation of ceramics is the selection of materials with specific properties and deciding their proportions. Then, these raw materials are ground finely and mixed well by

- Crushing into very fine particles.
- Mixing with additives to achieve desirable characteristics.

1.



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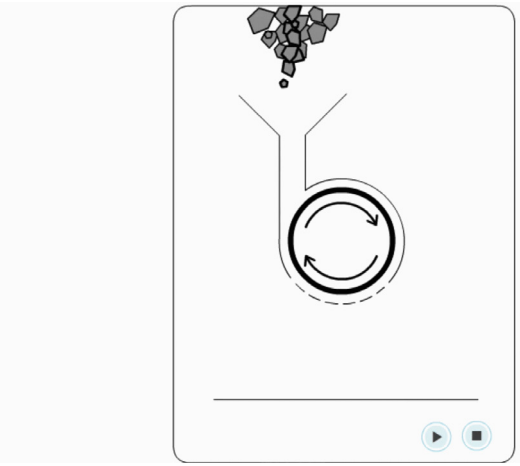

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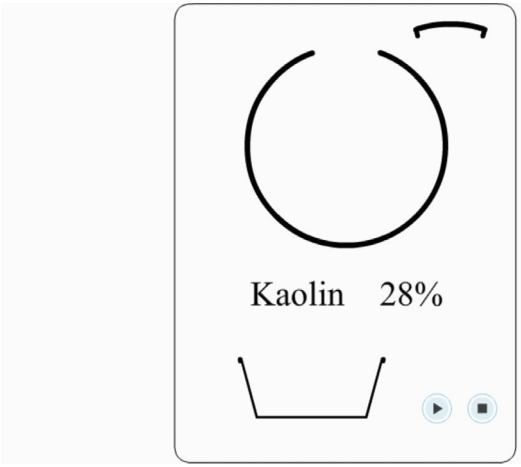
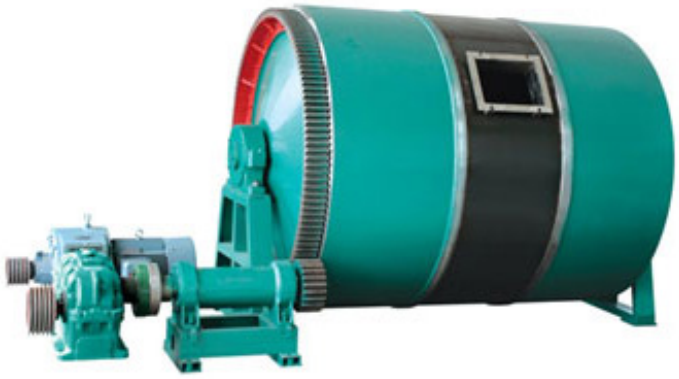


The above mentioned steps can be combined together in a single Ball Mill method. A ball mill is a cylindrical grinder used for grinding materials into extremely fine powder. The Ball mill is partially filled with the raw materials and grinding medium. The mill rotates about a horizontal axis and grinds the materials in fine particles.



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https://www.dsource.in/course/ceramics/types-manufacturing

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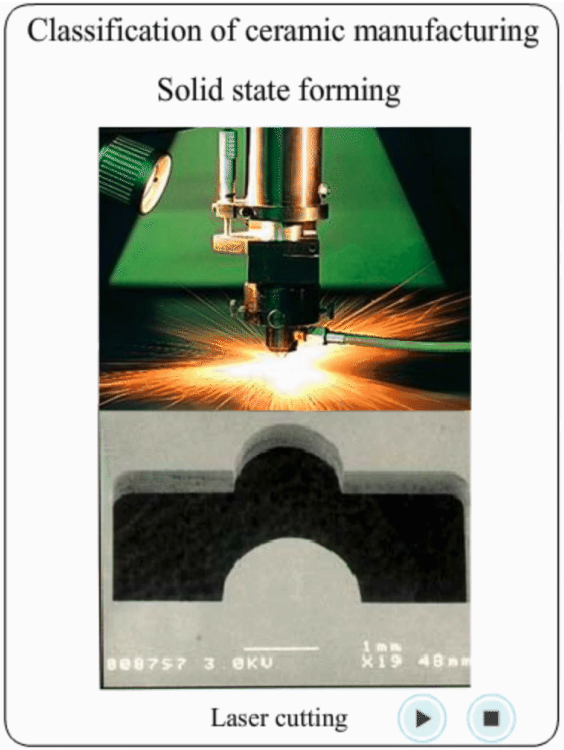
Types of Manufacturing

In any industrial production, various manufacturing processes or methods are used considering the desired technical, aesthetic and economic aspects of the final product. A broad knowledge of pros and cons of a manufacturing process is essential to be able to select the best suitable process inline to the work materials, geometry, surface finish and tolerances required. In case of shaping, we can divide the process of manufacturing depending upon the state of forming:

- Liquid state forming (LSF)
- Plastic state forming (PSF)
- Solid state forming (SSF)

All Process in brief is explained below:

Liquid State Forming (LSF):



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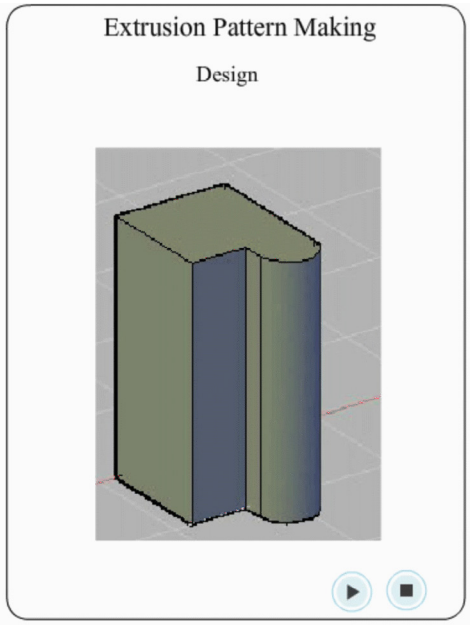
Plastic State Forming (PSF):



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Solid State Forming (SSF):

Animation and slides:
http://www.indiamart.com/macwell/metal-cutting-services.html
http://www.laserod.com/Nd-YAG_Laser_Machining_of_Alumina_Ceramic.shtm
http://eugenehon.blogspot.com/2011/04/slip-casting-decoy-duck-step-by-step.html
http://wpapotters.blogspot.com/2010/07/red-clay-tile-works-with-andy-anderson.html

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Source:
https://www.dsource.in/course/ceramics/liquid-state-forming

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Liquid State Forming

Liquid state forming (LSF) is a method used in ceramic industry for making products with specific forms. This state has fewer limitations in manufacturing forms and gives the designer ample freedom to design.

Liquid state forming is done in three steps:
- Pattern Making
- Mould Making
- Casting

Pattern Making

Mould Making

Slip Casting

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Pattern Making

The designer should decide the final form of the product. Then, the mould is prepared with the help of a pattern with a material best suited. Plaster is a good material for pattern making in ceramic industry. Making of symmetric and direct and twist extrusion patterns are explained further.

Symmetric Pattern Making : Roto-forming
Half outline of the product which is 50% larger than the real size (as the product shrinks twice, first while drying and then while firing the finished product) is drawn on a metal sheet. Then the metal sheet is cut along the outline and is fixed firmly on a frame to form the template.

Viscous wet plaster is slowly poured over an axel wrapped with wire mesh as reinforcement. The plaster sets around the rotating axel as the wire reinforcement helps in retaining the plaster around the axel. The fixed metal template preform helps the plaster to take the form as desired. The excess plaster gets shaved off from the surface to achieve the desired form. The inserted axel around which the desired plaster form is generated is then retracted.

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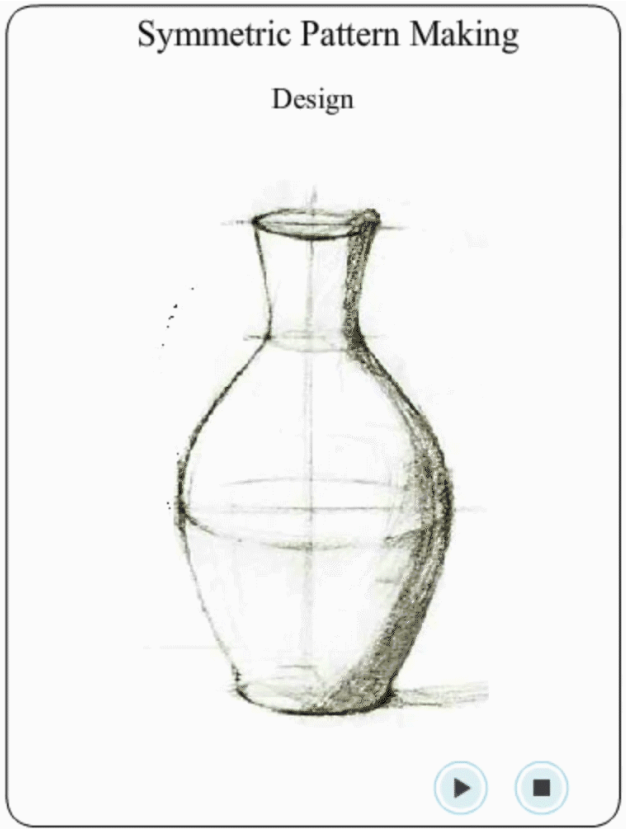

Direct and Twist Extrusion Pattern:
In this, we first cut the outline of the cross section of the product from a metal sheet to create a template. Please note that the size is 50% larger than the real size considering the shrinkage. Two diagonally opposite holes are punched on the sheet and passed through a fixed railing. This sheet metal template is guided up and down to extrude the desired form as viscous plaster is slowly poured and the template moved up and down taking off excess plaster from the pattern. This is done till the time the final extruded form is generated as a fine surface.

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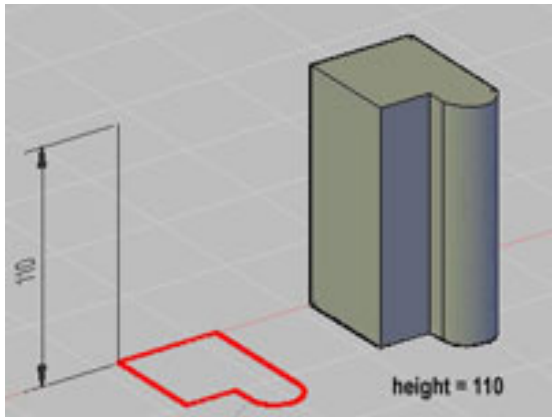

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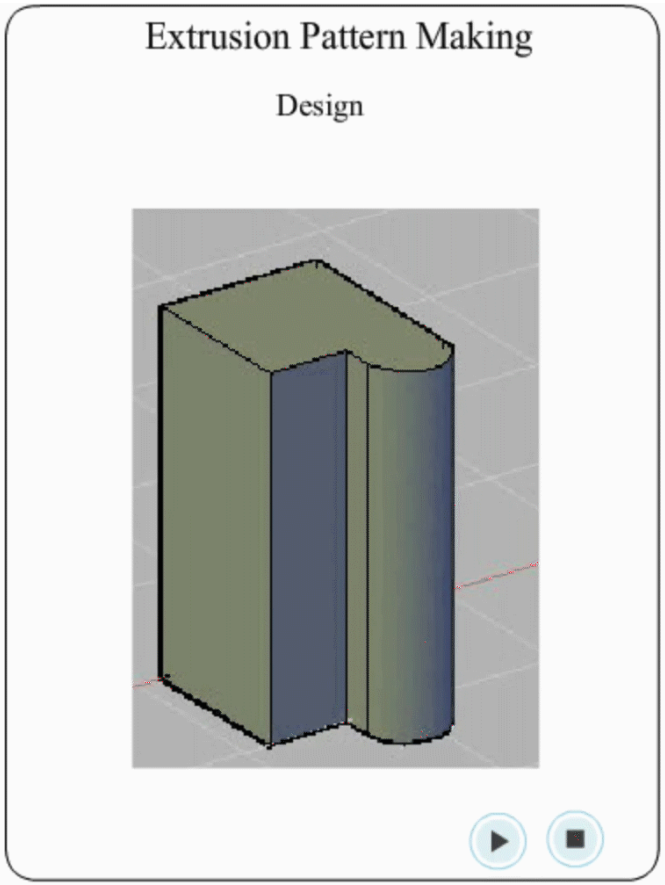

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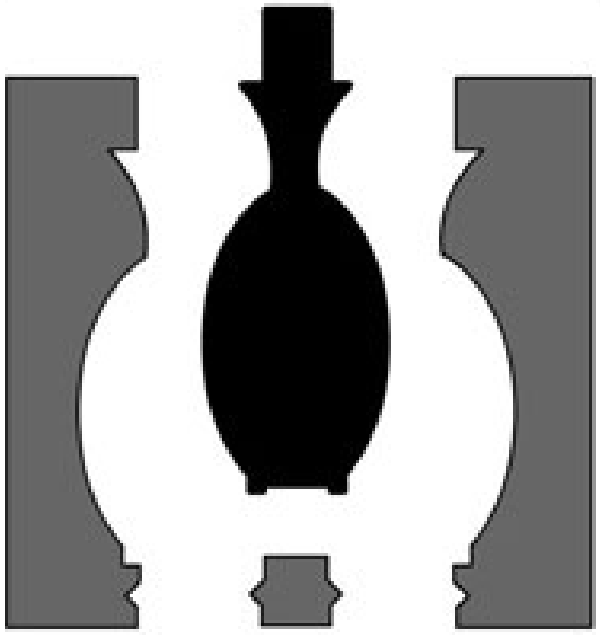
Mould Making

The mould is developed from a pattern and is made up of plaster for its ability to absorb water from the slurry as elaborated further. It is divided into two or more parts depending upon the complexity of the pattern which is explained in detail in the animation.

The area required to make the mould should be left open; closing the rest of it to ensure that the mould takes the desired form. Also, apply some oil or washing liquid as a separator to the plaster pattern. This will ensure that the pattern can be easily removed from the mould after casting.

It is essential to make the mould into minimum parts leaving enough space for carefully assembling them in a proper position.

The mould in the picture below is made into three parts. It is not feasible to make the mould in less than three parts and making it in four parts will degrade the quality of the product. Also, it is time consuming to match and fix the increased number of parts accurately. Hence, in this case it is most feasible to divide the mould into three parts to be very accurate.



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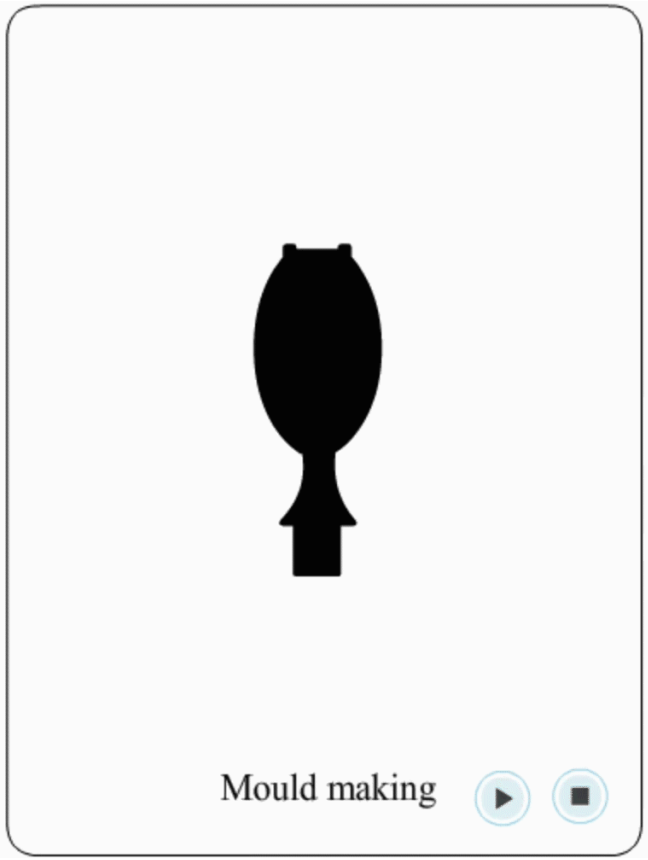

Source:
https://www.dsource.in/course/ceramics/liquid-state-forming/mould-making

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Slip Casting

Liquid state forming (LSF) is similar to casting of metals; the only difference being the use of ceramic slurry instead of molten metal. The entire process of casting is described further:

• In the beginning we join parts of mould and carefully fix them together with the aid of rubber band.

• Then, we pour the slurry of ceramics into the mould. As soon as the slurry settles down, we fill it up again. This is repeated according to the desired thickness of the product is achieved, considering the shrinkage after drying and also after firing. The inner surface of the mould absorbs water from the slurry in contact with and the slurry transforms into fine paste of clay. Depending on the size and thickness of the product, we allow the slurry to remain inside the mould.

• For Example: while making a teapot, the slurry is kept in the mould for about 5 minutes while in the case of twilight pen; it is kept for around 15 minutes.

• Once a desired thickness is achieved, the mould is inverted and the excess slurry is taken out leaving behind the paste of clay which takes a new shape of the inner surface of the mould.

• The product is taken out from the mould after 15 minutes. As the ceramic paste takes the shape of the mould, its size is smaller and seems to be an integral part of the mould.

• The wet product is then dried in shadow. And, finally, the raw product is fired in a furnace.

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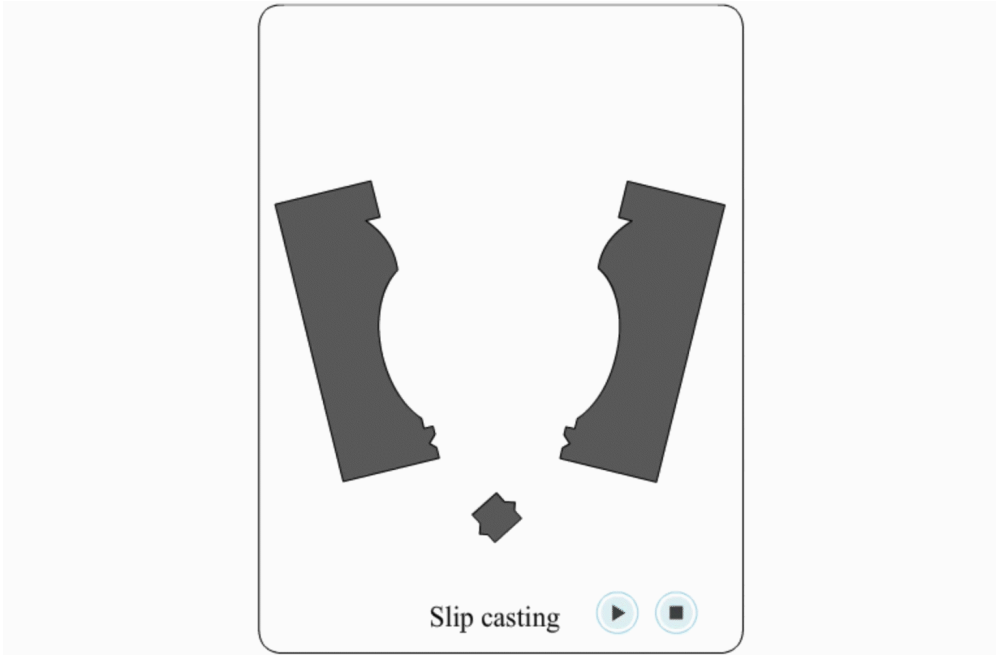

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Final Product:

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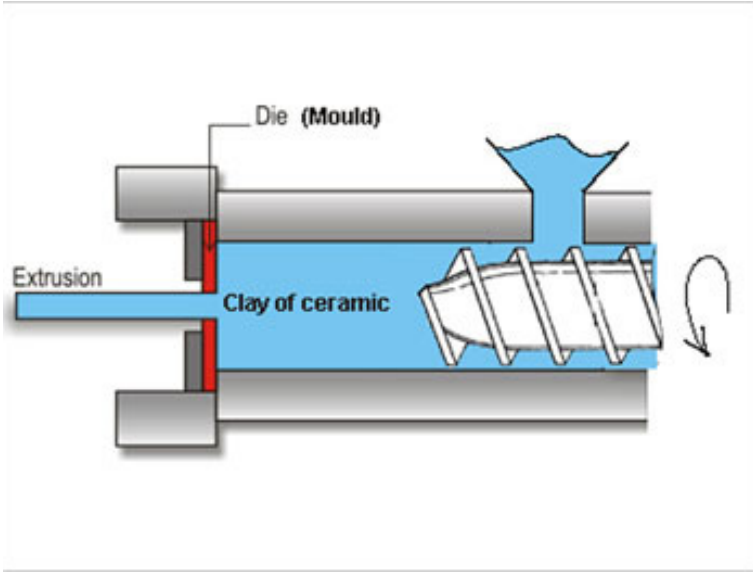
Plastic State Forming

Plastic state forming (PSF) involves making products from ceramics clay either by:
- Extrusion or
- Pressing Technique.

Extrusion:
The clay is pushed through a narrow die as shown in the figure. The products are usually very long and can be cut down to smaller parts to be used further in different process. As the ceramic flows out of the steel die, located at the other end of the container, the cross section of the product is defined by that of the die.



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Extrusion-Process:

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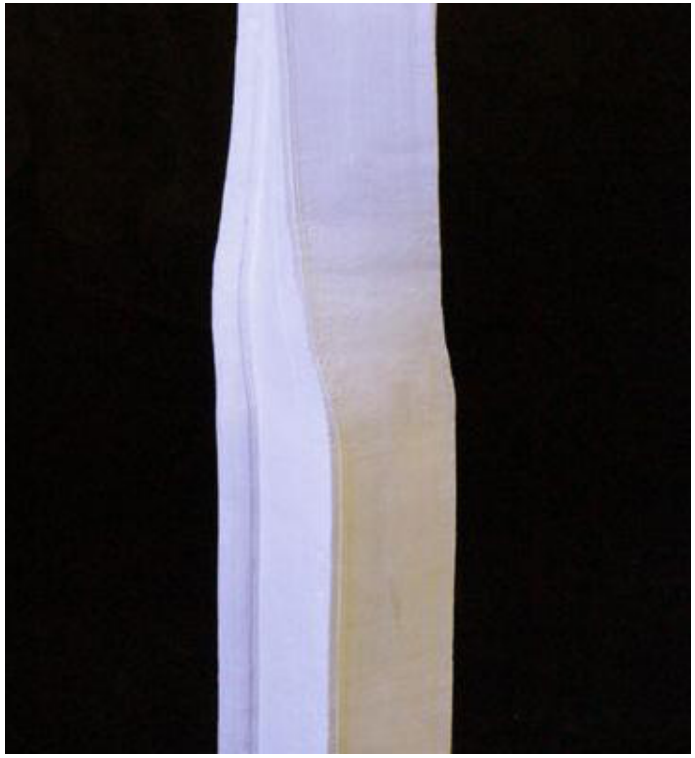

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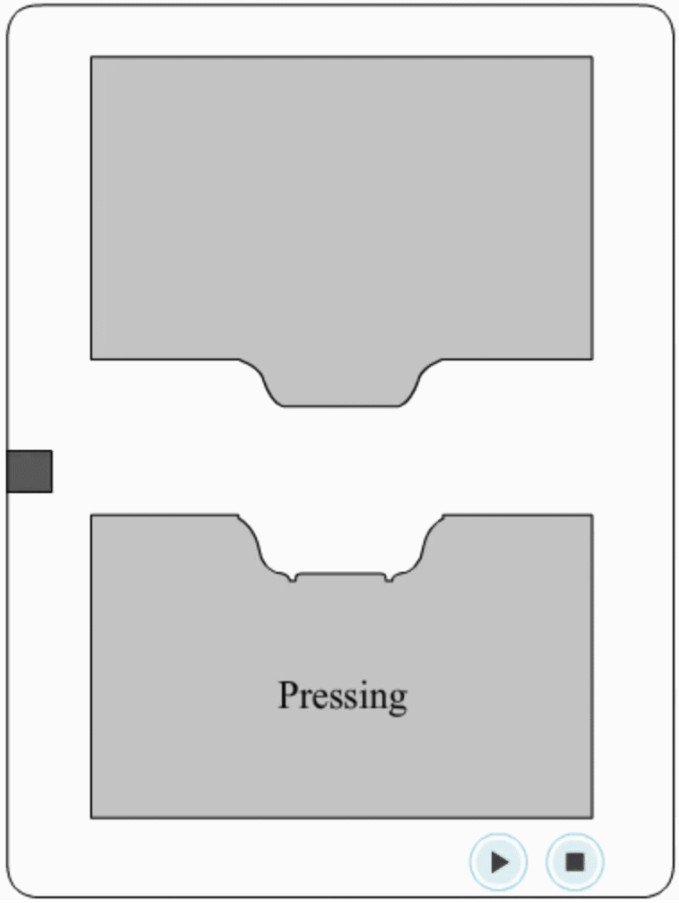
Pressing Technique:
In pressing, soft clay is put between the two parts of mould with a cavity of desired form and it is pressed. Thus, the clay takes the form of the mould as elaborated in the animation.



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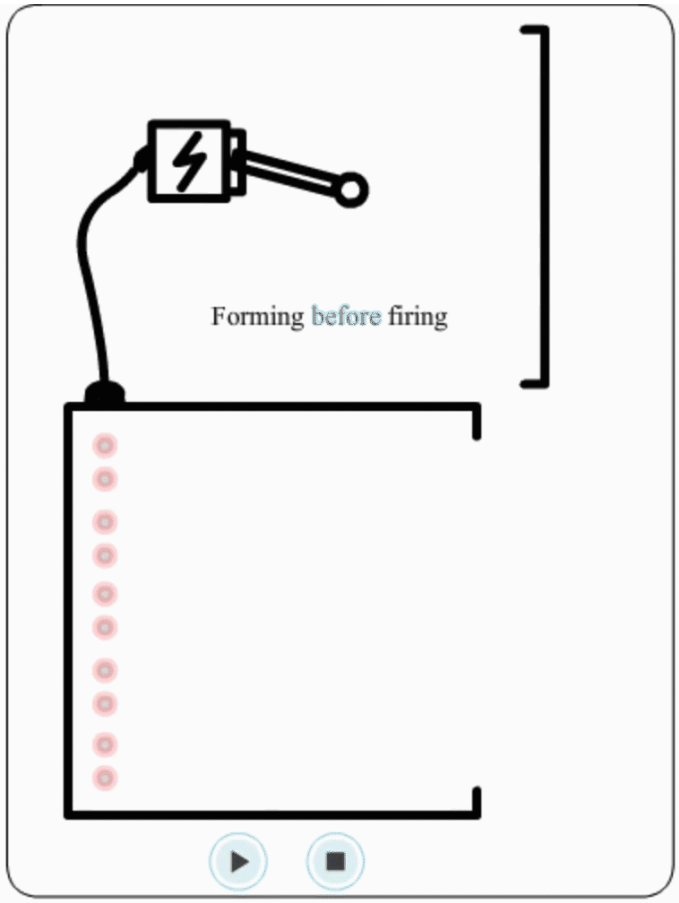
Solid State Forming

Solid State Forming (SSF) is another method in ceramic industry to make products with specific forms. It is divided into two types:

- Forming before firing
- Forming after firing

Forming before Firing:
Here, we dry the paste of ceramic to a solid. Then, we form it with normal tools like saw, drill, sand paper or simple process of turning etc.



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Forming after Firing:
The paste of ceramic is dried to a solid and fired. After that, we start forming with special tools like diamond blade, cutter (picture given below) or with laser, acid etc.

(Image source)

Laser Engraving Ceramic:
Engraving a ceramic product can completely change its appearance. Different types of techniques are used depending upon the type of the ceramic. Basically, some material is removed from the ceramic by laser and an 'engraved' mark is achieved. In some cases not only the top surface is affected, but also the underlying material. This is more common in commercial grade ceramic items such as earthenware.

Industrial ceramics are typically much more heat resistant and have a better quality front surface. Because of the surface condition, engraving is usually of the highest quality.

A special laser application on ceramic is the processing of special tiles (laser tiles) which can be directly inscribed with a CO_2 laser engraver and produce a rich and dark contrast.

The best time to engrave a ceramic product is before glazing. The rough ceramic is easy to engrave and subsequent glazing can protect the fresh engraving. The overall completion time for a product varies with the complexity of design.

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Joining-Finishing

• Joining:
Joining may be done either
- Before Firing or
- After Firing

Before Firing:
In this stage, the following process is followed:
. Decide the area of the parts to be joined.
. The joining area is cleaned with a wet sponge.
. Put some thick slurry of ceramics on the joining parts.
. Fix them together on each other.
. Again use a wet sponge to remove the extra slurry of ceramic from the joint and clean it thoroughly to get an even surface.

After Firing:
In this stage we can use mechanical fasteners and adhesives to join desired parts.

• Finishing:
Finishing involves the below mentioned steps:
- Cleaning and Glazing
- Painting
- Stickering and Printing

Cleaning and Glazing:
Cleaning:
After casting we should use a wet sponge to clean the surface of raw product at each stage. Sand paper can also be used depending upon the form.

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Glazing:
Glazing can change the chroma, value, hue and texture of a surface. Kaolin used for glazing is expensive hence it is mixed in small proportion with ceramic and applied on the product. After firing this product once, it is again glazed with higher proportion of Kaolin to enhance the appearance of the product. This technique is mainly useful for products made up of red clay.

Painting:
The products are painted (in firing) step by step beginning with the colors like dark red, brown and black that are fixed at higher temperatures. Then group of colors like lemon yellow and golden which require lower temperatures are used and then the product is put in the furnace for firing. If these groups of colors are used together and fired, then the colors that require lower temperature get burned and turn black.

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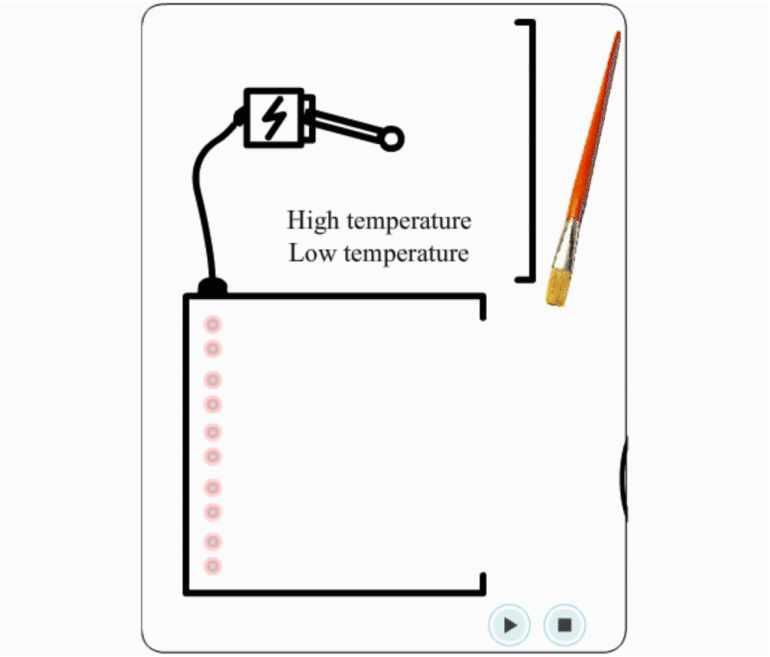

Stickering and Printing:
Painting described above is rather time consuming. Hence, in industry for mass production, Stickering and Printing are used. In these methods all the colours can be applied at the same time by adding a catalisor to the colors that require higher temperatures, which ensures that all the colours get fixed at a lower temperature.

In printing we can use silk print technique to print pattern on the ceramic product directly. While in stickering, the desired pattern printed on a transparent gelatin is placed on a special cardboard. Whenever it is required to be used, the cardboard is dipped in water. After few minutes the gelatin holding the colors, alone come off from the cardboard which is then directly applied on to the surface of the ceramic and is fixed permanently with firing.

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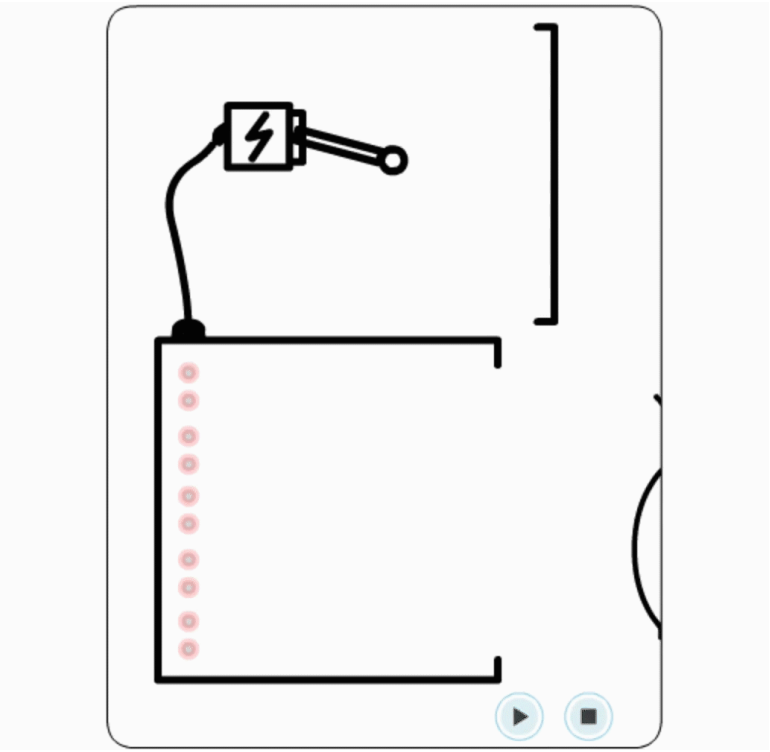
Firing

People in the early civilizations used clay to make their vessels and sculptures which they fired accidently; probably after discovering some burnt clay in a campfire. This very basic firing process evolved gradually into a more professional one.

For firing, unfired clay pottery or bisque fired pottery is covered with suitable burning materials and placed in a pit made in the ground. A bed of dry leaves, wood and coal that will burn slowly is laid at the bottom of the pit and the pottery is placed over this bed. The entire work is covered with more leaves and wood creating a pile. This pile is lit around the edges, once it is properly stacked and is left to smolder for several hours.

Today's ceramic industry is very much advanced and use specially designed furnaces that use petrol or electricity as a power source.

Remember, the ceramic product shrinks to a size 33% smaller than the original mould.



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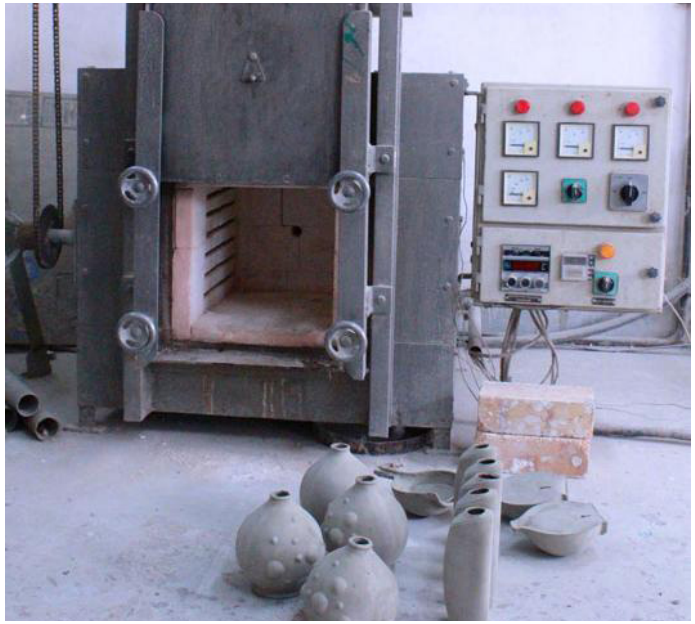
Firing Process:



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Ceramics

An Exploration of Form through Ceramics

by
Mohsen Jafaarnia and Prof. Ravi Mokashi Punekar
DoD, IIT Guwahati

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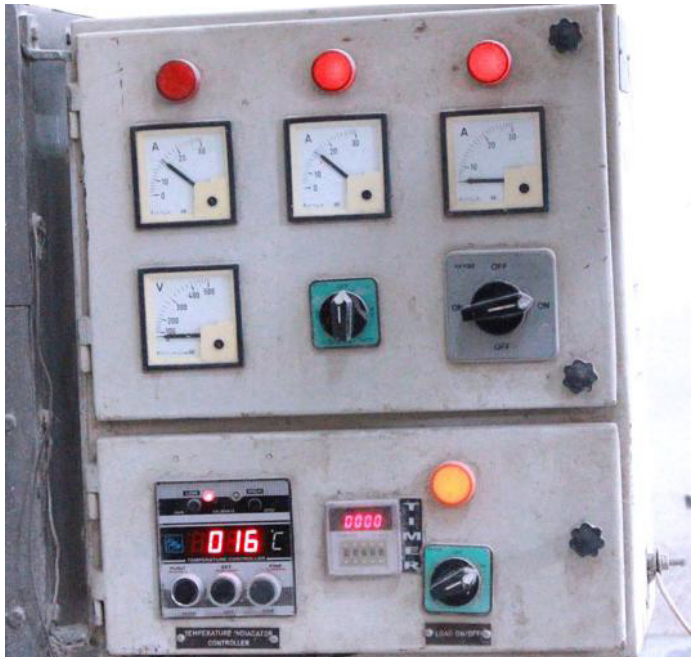

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Products

Few examples of products made of creramics:

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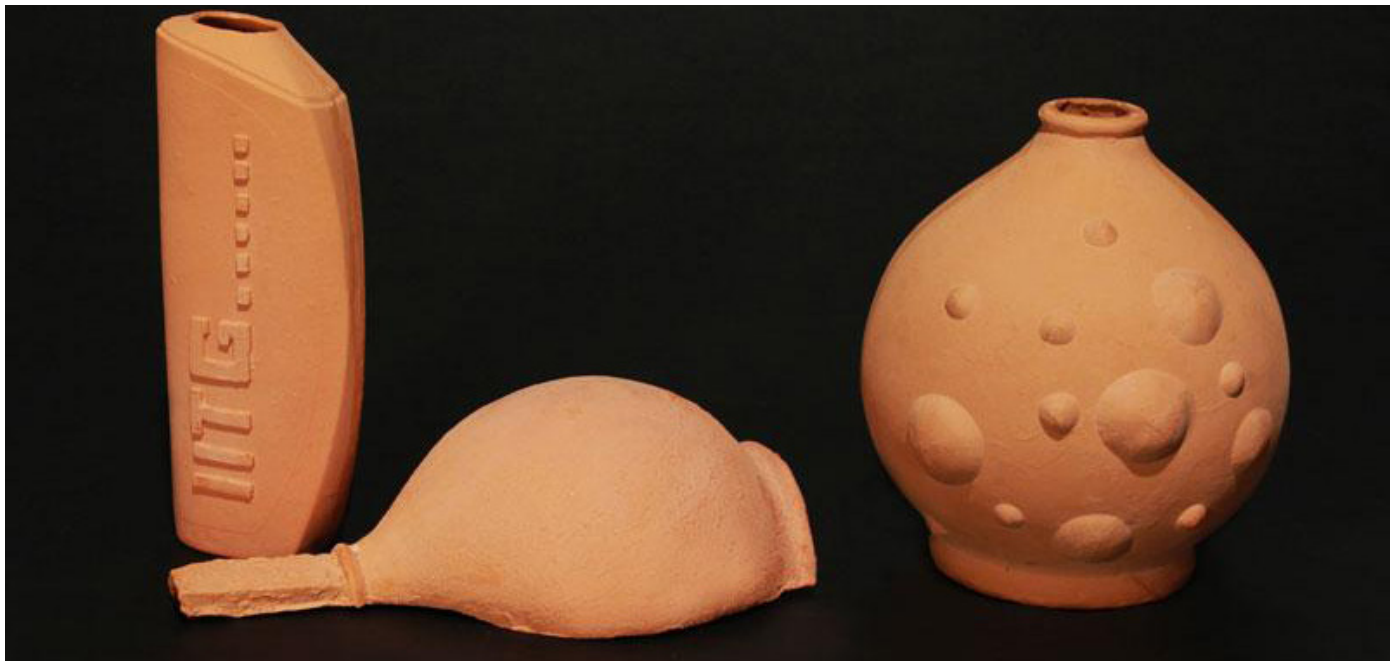

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Video

Sleep Casting and Firing

Process of Preparing Mould

Process of Extruding Symmetry Model

Process of Extruding Direct and Twist Model

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Contact Details

This documentation for the course was done by Mohsen Jafaarnia with Professor Ravi Mokashi Punekar, faculty at DoD, IIT Guwahati.

You can get in touch with him at mokashi[at]iitg.ernet.in

You can write to the following address regarding suggestions and clarifications:

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